

LABORATORY ASSESSMENT OF VACUUM-BASED CRACK MONITORING SENSOR



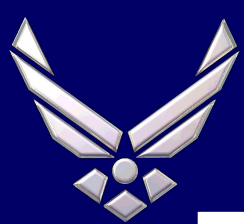
19 Jun 02

Ken LaCivita

**Materials Engineer
Air Force Research
Laboratory**

Duncan Barton

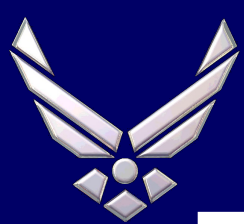
**R&D Manager
Structural Monitoring**



ACKNOWLEDGEMENTS



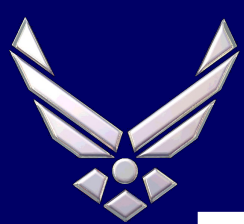
- **Mr Jack Coate - AFRL/MLSC**
- **Mr John Brausch - AFRL/MLSA**
- **Mr Keith McClellan - Structural Monitoring Systems, Ltd.**
- **Mr Michael Waddell - AFRL/MLO**



OUTLINE



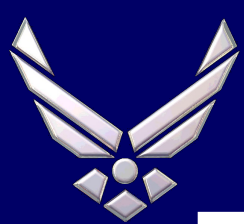
- **Background**
- **Similar Technologies**
- **Technology Description**
- **Testing**
- **Test Results**
- **Current Status of CVM Technology**
- **Conclusions/Recommendations**



BACKGROUND



- **AFRL was introduced to novel crack detection technology - Comparative Vacuum Monitoring (CVM™)**
 - **Developed by Structural Monitoring Systems (SMS) based in Australia**
 - **Nondestructive Evaluation (NDE) Team had interest in technology and an immediate need for real time crack detection monitoring**
- **Agreement was made for use of equipment in exchange for an informal assessment**

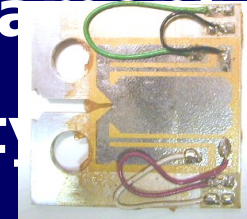
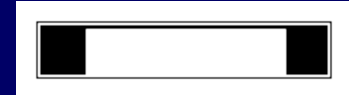


SIMILAR TECHNOLOGIES



- **Other crack detection/monitoring technologies:**

- Crack Detection Gage (filament-type)
- Crack Propagation Gage (filament-type)
- Crack Detection Gage (foil-type)

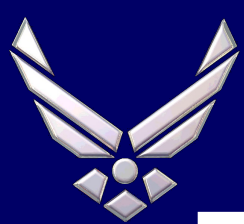


- Electro Potential Difference



Test Leads

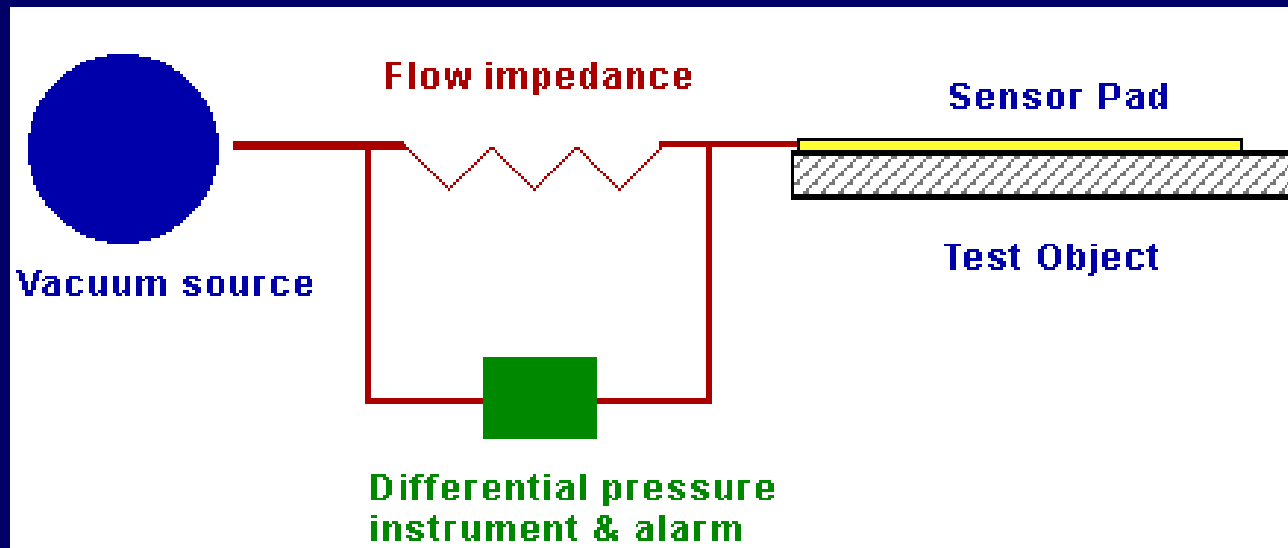
Test Article



TECHNOLOGY DESCRIPTION



- **CVM Concept:**
 - **Small volume under vacuum**
 - **Measure air ingress caused by leak (surface crack)**



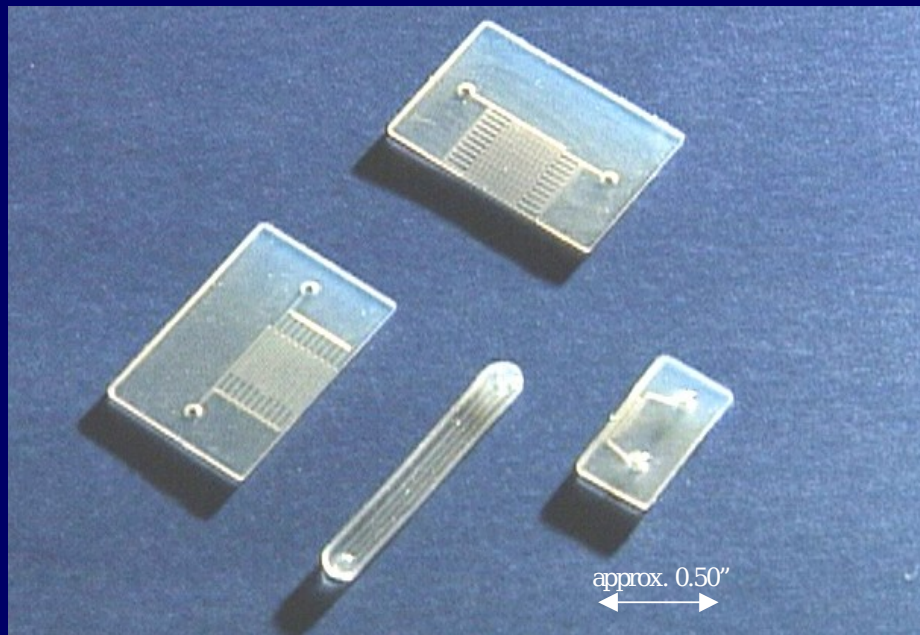
System schematic



TECHNOLOGY DESCRIPTION



- **Sensor Pad**
 - **Self adhesive, flexible polymer**
 - **Channels molded on one surface**



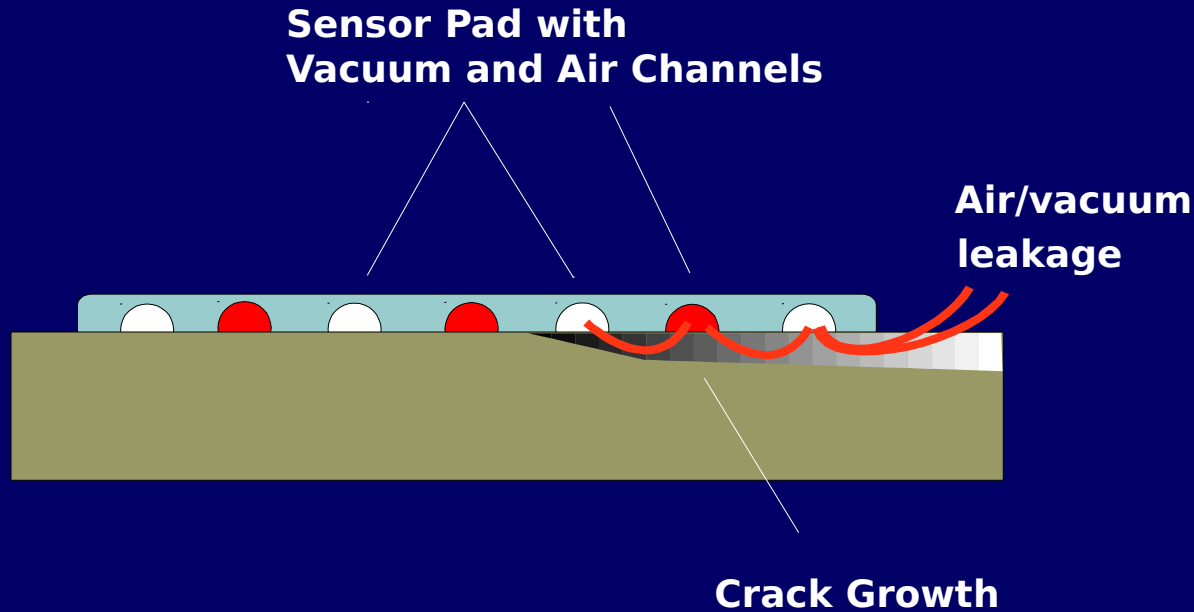
Typical sensor pads



TECHNOLOGY DESCRIPTION



- **Sensor Pad**
 - Crack growth beneath pad is detected when “vacuum gallery” is opened to atmospheric pressure

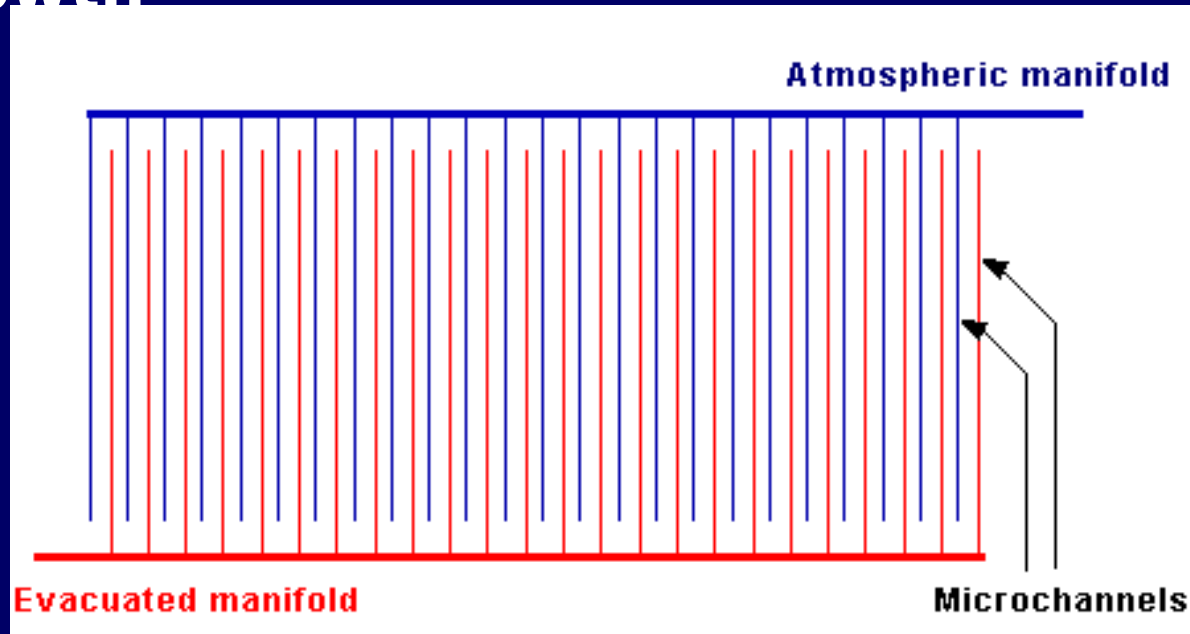




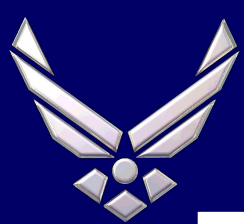
TECHNOLOGY DESCRIPTION



- **Sensor Pad**
 - **Configured for crack detection or crack growth**



Sensor pad schematic for crack detection

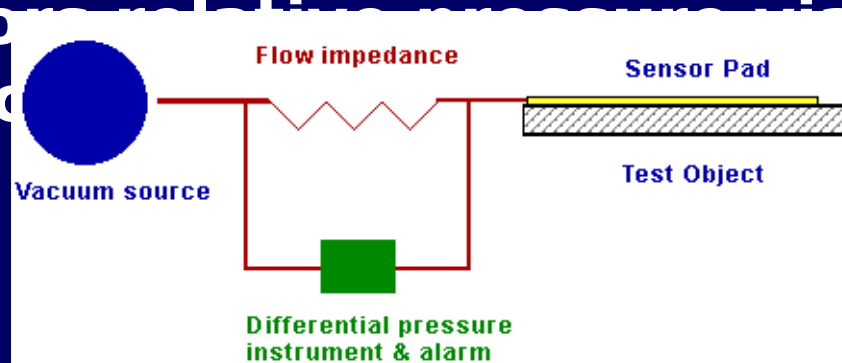


TECHNOLOGY DESCRIPTION



- **System Equipment:**
 - **Kvac (constant vacuum source)**
 - Pulls vacuum on sensor pad
 - Reference for relative pressure measurement
 - **SIM (flow sensing device)**

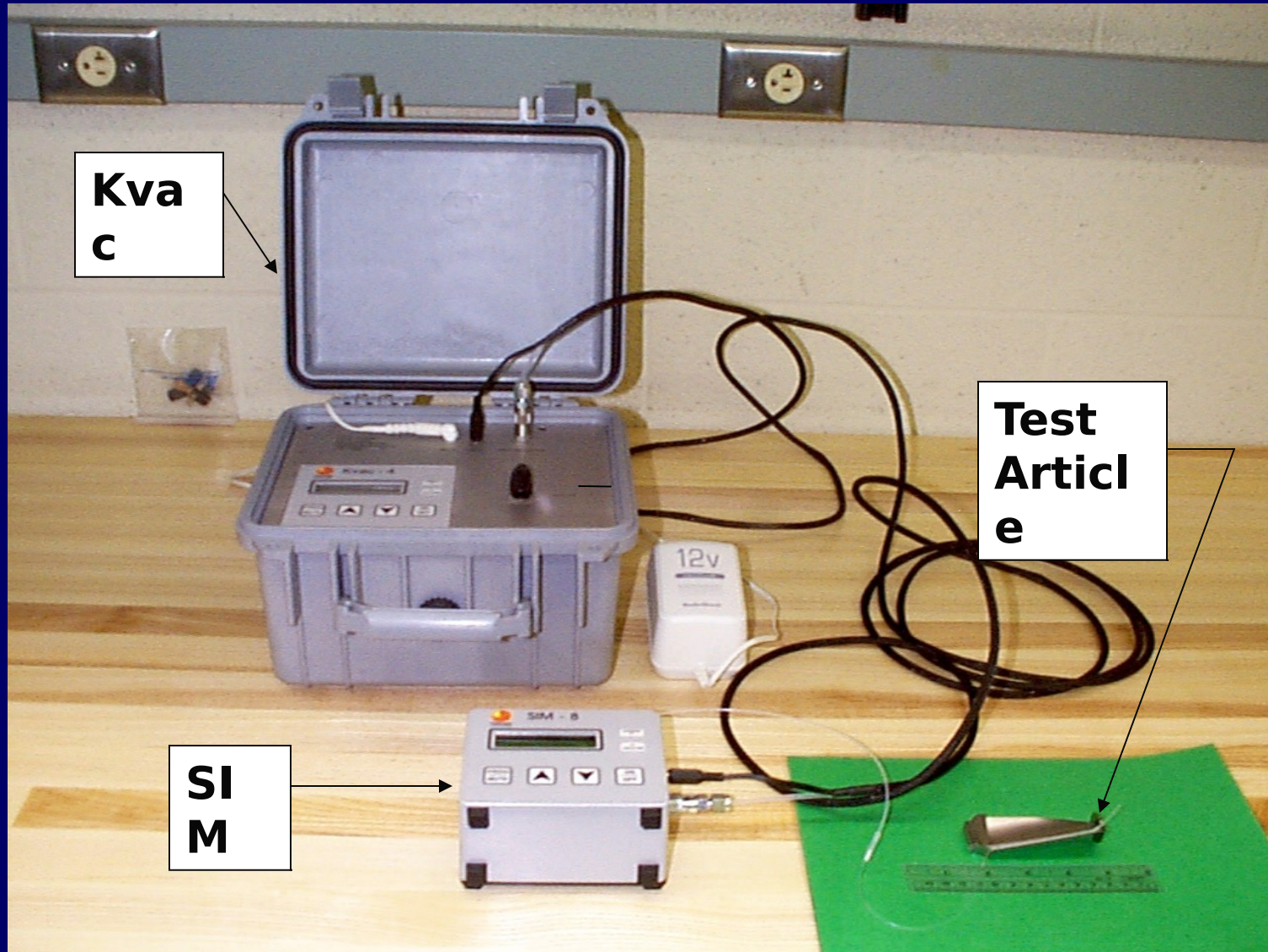
- **Monitor relative pressure** low
- **conduct**



System schematic



TECHNOLOGY DESCRIPTION

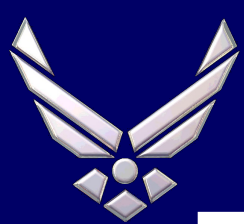




TESTING



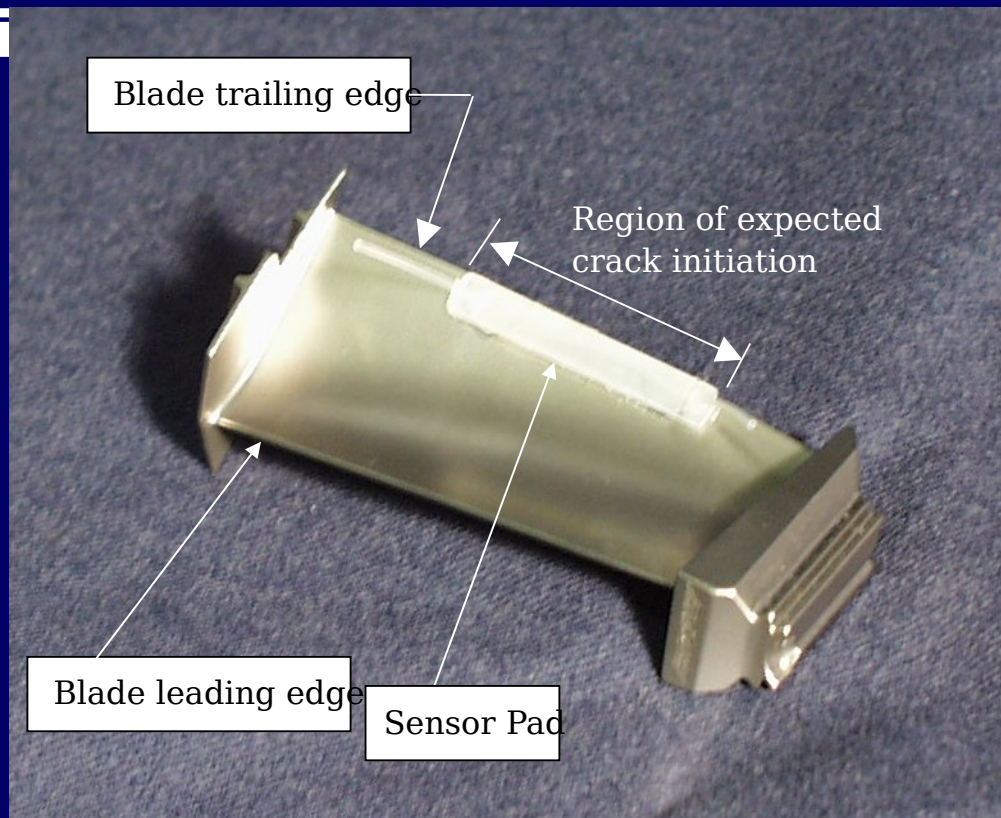
- **Primary purpose:**
 - **Grow natural cracks in engine turbine blades**
 - **0.020 - 0.080" WITHOUT starter notches**
- **Secondary purpose:**
 - **Evaluate novel vacuum-based sensor for lab applications**



TESTING



- **Test Article**
 - **Inconel 713 turbine blade**
 - **Edge crack desired perpendicular to trailing edge**

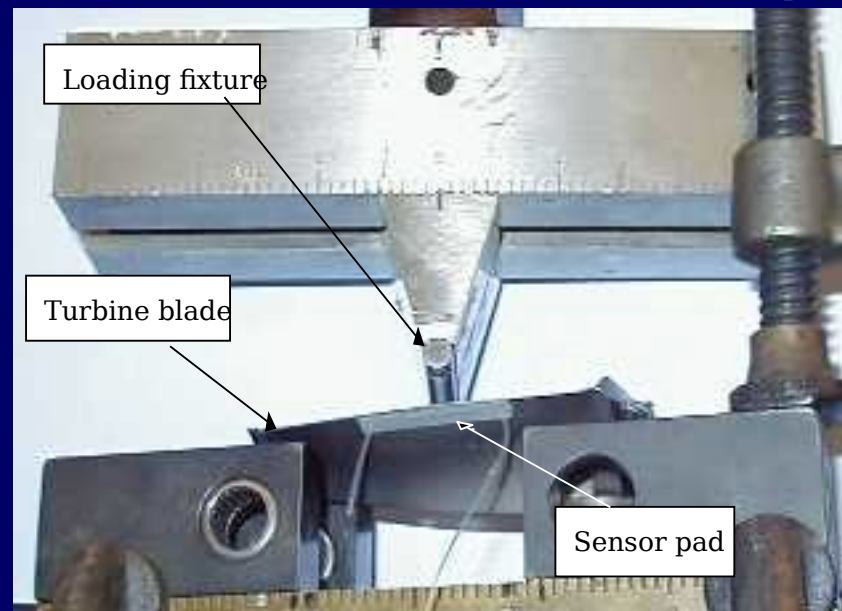


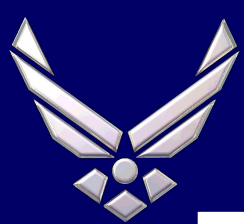


TESTING



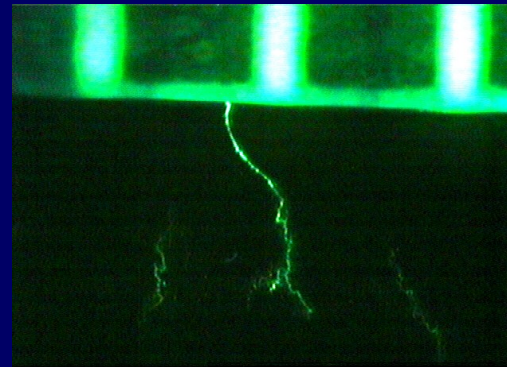
- **Test Approach**
 - **AFRL/MLSC Structural Test Facility**
 - **3 point cyclic bending**
 - **10 Hz, increase load every 10000 cycles**



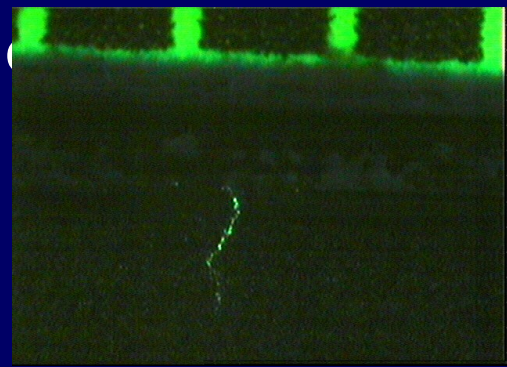
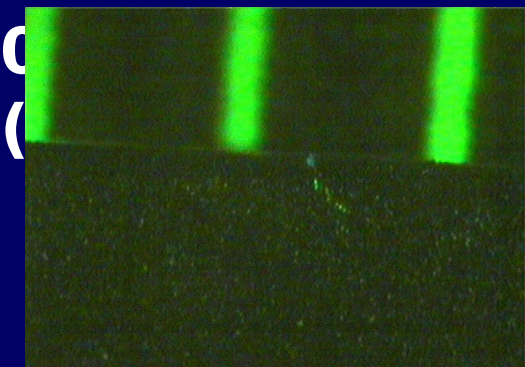


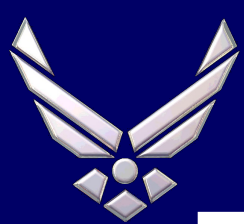
TEST RESULTS

- **Natural cracks detected in two blades**
 - **0.047" convex side/0.077" concave**



- **0.047" convex side/0.077" concave**





CURRENT STATUS OF CVM TECHNOLOGY



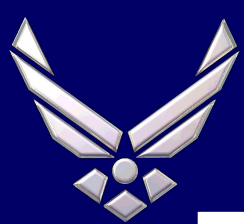
- **Failure Modes and Effects Analysis**
 - **Risks being examined for on-aircraft installation**
- **Independent tests of sensor and adhesive constituents**
 - **Neutral pH**
 - **Negligible mobile ions**
- **Performance through paint evaluated**
 - **Able to detect cracks through various thicknesses and ages of paint systems (note: paint cracked)**
- **Effect of long vacuum ducting evaluated**
 - **Sensitivity is governed by gallery spacing**



CURRENT STATUS OF CVM TECHNOLOGY



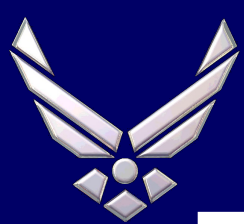
- **Portable in-field unit evaluation - IN WORK**
- **Validation trials on flying aircraft - IN WORK**
- **Long-term environmental program - PLANNED**
 - **Temperature and humidity extremes**
 - **Chemical and UV exposure**
 - **Sensors will be overcoated with sealant**



CONCLUSIONS/ RECOMMENDATIONS



- **Crack growth on turbine blade without starter notch proved challenging**
 - **Experimental test method - trial & error approach**
 - **Unpredictable crack growth rates**
 - **Dependent on test operator to stop test once crack detected**



CONCLUSIONS/ RECOMMENDATIONS



- **CVM is an effective alternative means for surface crack detection in a lab environment**
 - **0.020” sensitivity possible**
 - **User-friendly operation**
 - **Adheres with minimal surface prep**
 - **Complex geometry applications**
- **On-aircraft applications need further evaluation**